

**Research Proposal
for the use of
Neutron Science Facilities**

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20111556
Submission Number:
S1577
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03/14/11

☐ Fast Access ☐ Joint CINT Proposal

Program Advisory Subcommittee: Defense-related Nuclear Science			
Focus Area:			
Flight Path/Instrument: 1FP14 / DANCE		Dates Desired:	
Estimated Beam Time (days): 14		Impossible Dates:	
Days Recommended: 0			
TITLE Neutron capture measurements on 184W, 186W and natTa		<input checked="" type="checkbox"/> Continuation of Proposal #: S1385 20101555 <input type="checkbox"/> Ph.D Thesis for:	
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RESEARCH AREA		FUNDING AGENCY	
<input type="checkbox"/> Biological and Life Science <input type="checkbox"/> Chemistry <input type="checkbox"/> National Security <input type="checkbox"/> Earth Sciences <input type="checkbox"/> Engineering <input type="checkbox"/> Environmental Sciences <input checked="" type="checkbox"/> Nuc. Physics/chemistry <input type="checkbox"/> Astrophysics <input type="checkbox"/> Few Body Physics <input type="checkbox"/> Fund. Physics <input type="checkbox"/> Elec. Device Testing <input type="checkbox"/> Dosimetry/Med/Bio <input type="checkbox"/> Earth/Space Sciences <input type="checkbox"/> Materials Properties/Test <input type="checkbox"/> Other:		<input type="checkbox"/> Mat'l Science (incl Cond Matter) <input type="checkbox"/> Medical Applications <input type="checkbox"/> Nuclear Physics <input type="checkbox"/> Polymers <input type="checkbox"/> Physics (Excl Condensed Matter) <input type="checkbox"/> Instrument Development <input type="checkbox"/> Neutron Physics <input type="checkbox"/> Fission <input type="checkbox"/> Reactions <input type="checkbox"/> Spectroscopy <input type="checkbox"/> Nuc. Accel. Reactor Eng. <input checked="" type="checkbox"/> Def. Science/Weapons Physics <input type="checkbox"/> Radiography <input type="checkbox"/> Threat Reduction/Homeland Sec. <input type="checkbox"/> Other:	
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PUBLICATIONS**Publications:**

NONE

Abstract: S1577_LANSCE_Wprop.doc

By electronic submission, the Principal Investigator certifies that this information is correct to the best of their knowledge.

Safety and Feasibility Review*(to be completed by LANSCE Instrument Scientist/Responsible)*

- ☐ No further safety review required ☐ To be reviewed by Experiment Safety Committee
☐ Approved by Experiment Safety Committee, Date:

Recommended # of days:**Change PAC Subcommittee and/or
Focus Area to:****Change Instrument to:****Comments for PAC to consider:****Instrument scientist signature:****Date:**

Continuation of Neutron capture measurements on ^{184}W , ^{186}W and $^{\text{nat}}\text{Ta}$.

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We would like to finish experiments on W and Ta. Our original proposal from FY10 did not get enough beam time to conclude all the measurements and out of the requested 17 days we used only 3 days of the beam time (the original proposal FY10 is enclosed below).

We request 14 days of beam time,

to measure $^{184,186}\text{W}$ and $^{\text{nat}}\text{Ta}$ neutron capture cross sections at DANCE. A following time plan for the measurements is suggested:

Based on the calculated rates we request 5 days of beam time for ^{184}W target, 2 days of beam time for ^{186}W target, 2 days of beam time for $^{\text{nat}}\text{Ta}$ targets and 4 days of beam time for Pb target. In addition we will run 1 day on: Au targets (to calibrate the total neutron flux at the target position), shutter closed background, and shutter opened with no target background.

Preliminary results from 2010 December 1-3:

In Figure 1, DANCE data (black line) is compared to ENDF evaluated cross sections folded with the flight path 14 neutron flux (red line). The DANCE data is gated on $M=5-8$ yielding 18% detection efficiency. The background subtraction was achieved using the data on Pb-208. For incident neutron energies above 5 keV more careful background subtraction is needed and we have plans how to improve that. The discrepancies at first large resonance around 20 eV is caused by the self shielding and scattering effects. Though we included in the calculation (red line) the self-shielding effects the scattering contribution is not negligible and needs to be added to analysis. The experimental data show significant amount of pile up and we plan to study these effects using measurements with thin samples.

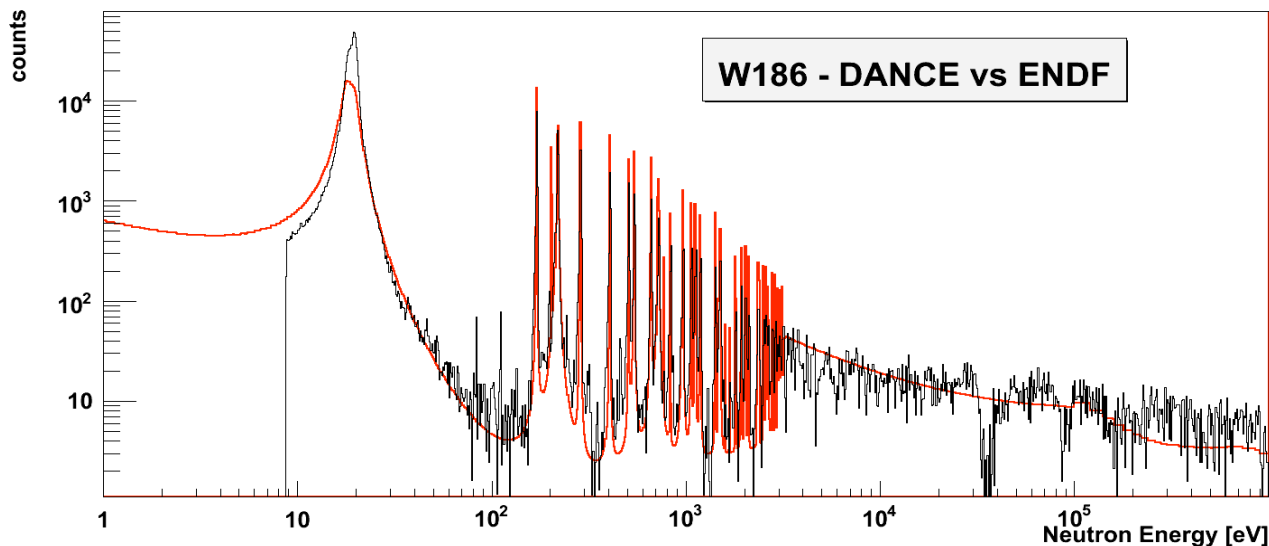


Figure 1 Counts corresponding to W -186(n,g) as measured at DANCE (black line) are compared to calculated values using ENDF cross section folded with neutron flux at flight path 14 (red line)

Neutron capture measurements on ^{184}W , ^{186}W and $^{\text{nat}}\text{Ta}$.

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1. Introduction

We propose to measure neutron capture cross sections on the stable isotopes of tungsten – ^{184}W and ^{186}W (both isotopic enriched) using the Detector for Advanced Neutron Capture Experiments (DANCE) on flight path 14 at Lujan Jr. Neutron Scattering Center. In addition, we propose to measure neutron capture cross section on $^{\text{nat}}\text{Ta}$. Both tungsten and tantalum are common materials and may be used in construction of nuclear devices. As such neutron activation of these materials are of interest to both nuclear forensics and stockpile stewardship. After neutron capture on ^{184}W , ^{186}W and ^{181}Ta , the moderately-short lived isotopes ^{185}W ($t_{1/2}=75$ days), ^{186}W ($t_{1/2}=23.7$ hours) and ^{182}Ta ($t_{1/2}=114.4$ days) are produced. To interpret the yields of these radioactive isotopes, we need improved neutron capture cross section measurements.

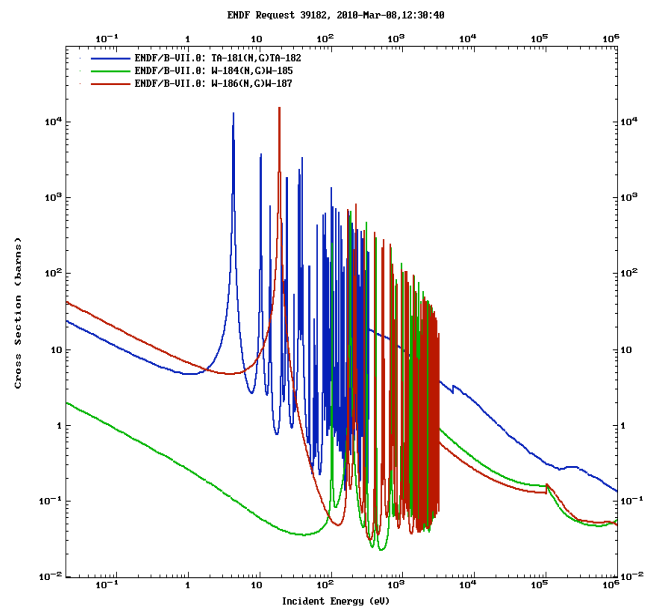


Figure 1 Neutron capture cross sections of ^{184}W , ^{186}W and ^{181}Ta taken from ENDF/B-VII evaluation.

2. Summary of existing measurements

There are many neutron capture measurements on W isotopes. The most significant ones are summarized in Table 1. However, there are no measurements using modern 4π arrays such as DANCE, where the effects of background are understood much better compared to methods using Moxon-Rae or other type of detectors. The spread of experimental results is large for both ^{184}W and ^{186}W and more accurate data is needed. In case of ^{181}Ta , there are two modern experiments carried out at Karlsruhe using similar experimental set-up as DANCE [Wis04,Wis90]. However, DANCE will provide more consistent data over a wider neutron energy region.

Table 1 Summary of neutron capture cross section experiments on $^{184,186}\text{W}$ and ^{181}Ta .

Ref	Target	Neutron Source	Neutron Energy	Detection Method
Wis04	^{181}Ta	The 3.75 MV pulsed Van de Graaff, Karlsruhe, Germany. The Li-7(p,n)-reaction	10 keV – 80 keV	Capture gamma: Karlsruhe 4Pi-Ba-F2 Detector Consisting of 29 Hexagonal and 12 Pentagonal Crystals Forming A Spherical Ba-F2 Shell of 15 Cm Thickness and 10 Cm Inner Radius. Resolution is 7% at 2.5 MeV Gamma Energy, Peak Efficiency 90 % at 1 MeV Neutrons: Li-6 glass detector as neutron flux monitor
Wis90	^{181}Ta	The 3MV pulsed Van de Graaff, Karlsruhe, Germany. The Li-7(p,n)-reaction	3 keV – 150 keV	Capture gamma: 42 4-Pi BaF2 crystals used as a calorimeter. Neutrons: Li-6 glass detector as neutron flux monitor
Kon96	^{181}Ta	Van de Graaff, Obninsk, Russia Li-7(p,n)Be-7	2.75 keV – 440 keV	Capture gamma: liquid scintillator detector of 17 l volume. Neutron flux: Li-6 detector (1mm Li-6 glass) B-10 plate and two NaT(Tl) crystals
Bok86	^{184}W ^{186}W	Van de Graaff, Obninsk, Russia Li-7(p,n)Be-7	(tof) flight path - 2.4 m for 20-400 keV and 2-20 eV neutron energy ranges and 0.72 m -for 4-140 keV	Capture gamma: liquid scintillator detector of 17 l volume. Neutron flux: Li-6 detector (1mm Li-6 glass) B-10 plate and two NaT(Tl) crystals
Mac84	^{181}Ta	(LINAC) ORELA, Oak Ridge	2.6 keV – 1.9 MeV	Capture gammas: NE226 liquid scintillator Neutrons: Li-6 glass flux monitor
Mac83	^{184}W ^{186}W	(LINAC) ORELA, Oak Ridge	(tof) 40.12 meter flight path: En=2.6 eV – 2 MeV	Capture gamma: two (c) 6 (f) 6 liquid scintillators Neutrons: 0.5 mm 6-Li glass flux monitor
Ref82	^{181}Ta	The 3 MV pulsed Van de Graaff, Karlsruhe, Germany. The Li-7(p,n)-reaction	11.83 keV – 60.2 keV	Capture Gamma: Moxon-Rae detector Neutrons: A Li-6 glass flux monitor at 20 degrees. Normalization: (79-Au-197(n,g)79-Au-198)
Blo66	$^{182-186}\text{W}$	(LINAC) ORELA, Oak Ridge	(tof) 25 meter flight path En=1 keV -9 keV	Capture gamma: 1.25 meter diameter liquid scintillator total: NaI(Tl) crystals
Bon05	^{184}W	LWR-15 reactor at rez near Prague	^{184}W (92.67%) of about 1.1 g was irradiated with thermal neutrons En=thermal	Capture gamma: Two HPGe detectors were used. gamma-rays from the target are viewed by a 28% detector with a resolution of 2 keV (FWHM) at 60co lines and about 5 keV at 5-6 MeV and a 25% detector with approximately the same resolution.

Ref	Target	Neutron Source	Neutron Energy	Detection Method
Bee81	^{184}W	<p>The 3 MV pulsed Van de Graaff; Forschungszentrum Karlsruhe, Germany</p> <p>The Li-7(p,n)-reaction using a water cooled target and a proton beam energy 20 keV above the reaction threshold to obtain a kinematically collimated neutron beam.</p>	<p>Time of flight techniques with prompt gamma-ray detection.</p> <p>En=5 keV – 93 keV</p>	<p>Capture Gamma: Moxon-Rae detector, consisting of a 2.5 cm thick graphite converter and a ^{111}Li plastic scintillator. the detector was placed at a 120 degree- backward angle.</p> <p>Neutrons: A Li-6 glass flux monitor at 20 degrees.</p> <p>Normalization: (^{79}Au-$^{197}\text{n,g}$)/(^{79}Au-198) data taken from ENDF/B-IV.</p>
Bee81	^{184}W	The h-3(p,n)-reaction using water cooled target and a proton beam energy 100 keV above the reaction threshold to obtain a kinematically collimated neutron beam.	<p>Time of flight techniques with prompt gamma ray detection.</p> <p>En=65 keV – 172 keV</p>	same as above
Kap66	^{186}W	Fiz. Inst. Lebedev (FIAN), Moscow, USSR	Slowing down time 10 eV – 50 keV	
Kon65	^{184}W ^{186}W ^{181}Ta	<p>Cockroft-Walton pulsed accelerator of protons with maximum energy of protons 1.2 MeV</p> <p>Using p,t reaction</p>	<p>Time of flight method with time resolution 20.-30.nsec and flight path 1.5 m:</p> <p>En=33 keV – 168 keV</p>	<p>Capture Gammas: Liquid scintillation detector with volume $0.5 \times 0.5 \times 0.5 \text{ m}^3$</p>
Mox68	^{181}Ta	(LINAC) Harwell Linac	Time of flight - 90 m. 100 eV – 16.6 keV	Capture gamma: Moxon-Rae detector High resolution dataset.
Mis62	^{186}W	<p>Van de Graaff; Lawrence Livermore National Laboratory, Livermore, CA, USA</p> <p>Li-7(p,n) & t(p,n)</p>	<p>32 keV – 247 keV</p> <p>69 keV – 3.97 MeV</p>	Activation. Reference $^{235}\text{U}(\text{n},\text{f})$.

ENDF Request 38498, 2010-Mar-04, 17:49:20
EXFOR Request: 61794/1, 2010-Mar-04 17:52:36

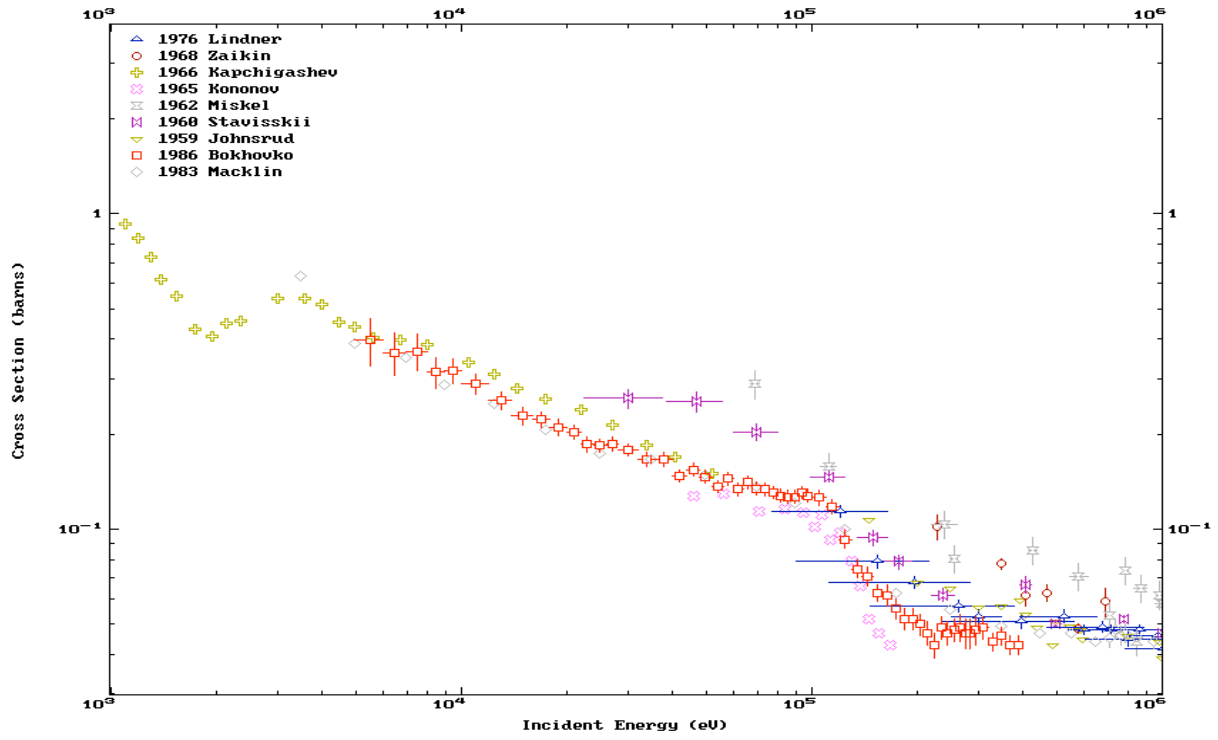


Figure 2 Measurements of $^{186}\text{W}(n, \gamma)$ cross section taken from EXFOR library.

The tungsten targets will be prepared from isotopically enriched tungsten powders pressed to 5 mm diameter pellets. The isotopic composition of tungsten material is following:

- a) ^{184}W (93.79 %), ^{182}W (2.34 %), ^{186}W (1.96 %), ^{183}W (1.91 %), ^{180}W (<0.03%)
b) ^{186}W (97.06 %), ^{184}W (2.16 %), ^{182}W (0.45 %), ^{183}W (0.33 %), ^{180}W (<0.02%).

The pallets will be placed in the center of a DANCE aluminum target holder using very thin mylar foils.

We will use the white source of neutrons at Lujan Jr. Neutron Scattering Center, that are produced in

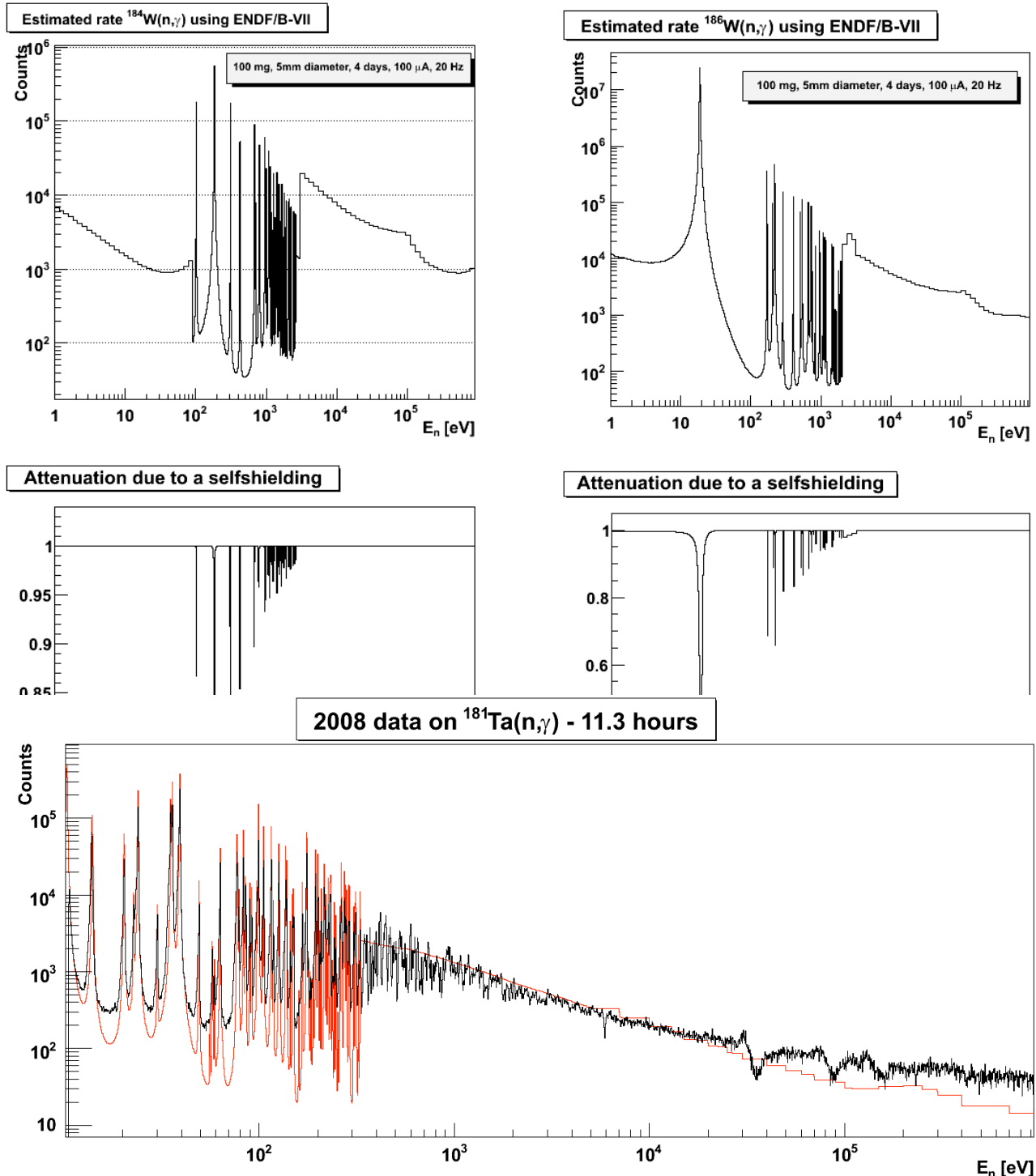


Figure 8 Data taken in 2008 on 21.2 mg/cm² self-supporting target of ^{181}Ta during 11.3 hours (black line). The red line shows the estimate for 11.3 hours of running at DANCE using ENDF/B-VII evaluation for comparison. We used 500 neutron

800-MeV proton-induced reactions on tungsten spallation targets. DANCE is located on flight path 14 and the targets in the center of DANCE are illuminated with neutrons from the spallation source that are moderated by a water moderator located on the upper tier of the spallation target assembly.

Capture gamma-rays will be measured using DANCE. The capture gamma-ray cascades will be identified using the selection of gamma-ray multiplicity and gamma-ray total energy cuts, to distinguish the neutron capture events from the background. DANCE will be run in the double continuous mode and we will cover the incident neutron energy region from 8 eV to 1 MeV. In addition to the measurements with W and Ta targets we will need to take data that will be used for the background subtraction. We expect that the main component of the background will be due to the neutron scattering off the target material (W, and Ta). We propose to use a ^{208}Pb target for this purpose because of its smooth elastic cross section behavior and very small (negligible) neutron capture cross section. In previous experiments, ^{208}Pb proved to be a good estimate of the background due to a neutron scattering background. In case of large external backgrounds, we will need to use data from other experiments.

We will prepare tungsten targets with the total mass of 50 mg and 100 mg to study the effects of self shielding, neutron multiple scattering and capture gamma-ray attenuation in the targets. We don't expect that these effects will be strong at neutron energies above 1 keV, but they will be significant in the resonance region. We estimated the number of counts we will accumulate at DANCE for 100 mg $^{184,186}\text{W}$ targets with 5 mm diameter and the results are shown in Figure 5 and 6. The rate was calculated using the typical running condition, with the accelerator proton current fixed at 100 μA and the repetition rate 20 Hz. We also assumed 15 % efficiency to positively identify the gamma-ray capture cascades at DANCE. (Typically, we put gates on gamma-ray multiplicity and gamma-ray total energy to achieve the best signal-to-background ratio. The 15 % efficiency is merely an estimate for the case of W isotopes and we hope that the efficiency will be higher than this.) In addition, to obtain better statistics, for ^{184}W we used 10% wide neutron energy bins from 1 eV – 80 eV, then for resonance region 80 eV – 3 keV we used 1 % wide bins, and finally for fast neutron energy region above 3 keV we used 15 % energy bins. For ^{186}W we used 1 % wide energy bins up to 3 keV and 15 % above 1 keV.

In case of Ta, we have already taken 11.3 hours on self-supporting 21.2 mg/cm² Ta foil in 2008 (see Figure 8). We calculated expected number of counts for total of 2 days (we request additional 1 day) of data using this foil and the results are shown on Figure 7 - we used 1 % energy bins up to 1 keV and 15 % wide bins above 1 keV. We assumed the same experimental conditions for DANCE and accelerator as for the W targets.

4. Beam time request

Based on the calculated rates we request 5 days of beam time for ^{184}W target, 5 days of beam time for ^{186}W target, 2 days of beam time for $^{\text{nat}}\text{Ta}$ targets and 4 days of beam time for Pb target. In addition we will run 1 day on: Au targets (to calibrate the total neutron flux at the target position), shutter closed background, and shutter opened with no target background.

In total, we request 17 days of the beam time to complete these measurements.

References

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